SINGLE WAVELENGTH OPTICAL TRANSCEIVER

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FIELD OF THE INVENTION

This invention relates to an optical transceiver for transmitting and receiving signals of the same wavelength, i.e. a single wavelength transceiver. It also relates to a transceiver unit incorporating such an optical transceiver and to a transceiver system comprising a plurality of such transceiver units.

BACKGROUND ART

Multi-wavelength transceivers which transmit on one wavelength and receive on another wavelength are known. Transmission and reception may occur on a bi-directional optical transmission path but the signals can be separated due to their different wavelengths. Single wavelength transceivers in which transmission and reception occurs along a bi-directional optical transmission path are also known. Such devices comprise a light source and light receiver which are connected to the bi-directional optical transmission path via a fixed power splitter, such as a Y-junction or evanescent coupler. In such an arrangement, both the light source and light receiver are permanently connected to the bi-directional light transmission path so incoming signals are transmitted to both the light source and the light receiver so a compromise has to be reached in the design of the splitter between the output power of the transceiver and the responsivity of the receiver.

The present invention seeks to overcome or reduce this disadvantage of the prior art.

DISCLOSURE OF INVENTION

According to a first aspect of the present invention, there is provided an optical transceiver for transmitting and receiving optical signals of the same wavelength, the transceiver comprising a light source, a light receiver, and input – output means for receiving light from and transmitting light to a bi-directional

optical transmission path, optical switching means being provided to selectively provide optical communication between the light source and the input-output means and between the input-output means and the light receiver.

According to a second aspect of the invention, there is provided a transceiver unit for receiving signals of more than one wavelength, the unit comprising a wavelength division multiplexer for separating the signals of different wavelengths and an optical transceiver as indicated above connected to receive signals of a first wavelength from the wavelength division multiplexer.

According to a further aspect of the invention, there is provided a transceiver system comprising a central unit connected to a plurality of such transceiver units and comprising a digital transceiver for communicating with the optical transceiver of each of the transceiver units. Each transceiver unit may also comprise a further receiver and the central unit a further transmitter for transmitting signals of a second wavelength to each of the transceiver units.

Preferred and optional features of the invention will be apparent from the following description and from the subsidiary claims of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, merely by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a first embodiment of a transceiver according to the present invention;

Figure 2 is a schematic diagram of a second embodiment of a transceiver according to the present invention;

Figure 3 and 4 are schematic diagrams showing two possible arrangements of components for forming the transceivers of Figures 1 and 2;

Figure 5 is a schematic diagram illustrating an application of a modified form of a transceiver such as that shown in Figure 3;

Figure 6 is a schematic diagram of a p-i-n diode phase modulator used in a preferred embodiment of the invention; and

Figures 7 and 8 are schematic diagrams illustrating a further application of a transceiver according to the invention.

BEST MODE OF CARRYING OUT THE INVENTION

Figure 1 shows an integrated optical transceiver formed on a chip 1. The transceiver comprises a light source 2, such as a laser diode, a light receiver 3, such as a photodiode, and a fibre optic connector 4, for receiving an optical fibre 5 on the edge of the chip 1. The light source 2, light receiver 3 and fibre optic connector 4 are each connected to optical switching means 6 by waveguides integrated on the chip 1.

The optical switching means 6 is arranged to selectively provide optical communication between the optical fibre and the light source 2 or the light receiver 3. Figure 1 therefore represents switching means 6 in the form of a 2-way switch. The switching means 6 will be described further below with reference to Figures 3 and 6.

The transceiver is arranged to transmit and receive signals of the same wavelength over the optical fibre 5. The bi-directional signals transmitted over the fibre 5 may be compressed into data packets whereby input and output data can be allocated to specific time slots. By appropriate control of the switching means 6, the light source 2 can be connected to the optical fibre 5 during a transmission time slot and the light receiver 3 connected to the optical fibre 5 during a receiving time slot. It will be appreciated that the switching speed should be fast enough to ensure there is only a small dead-time between

transmit and receive time slots. By operating the switching means 6 in this way, it provides a low-loss path between the light source 2 and the fibre 5 and a low-loss path between the light receiver 3 and the fibre 5. The design compromise imposed by a passive coupler as used in the prior art is thus avoided and the optical losses associated therewith can be reduced or eliminated.

The optical switching means 6 comprises an actively controlled integrated optical switch. For relatively low data rate applications, the optical switch may comprise one or more thermal modulators but for faster data rate application, the optical switch is preferably based on one or more p-i-n diode phase modulators. Other forms of modulator may be used in the optical switch.

A p-i-n diode phase modulator formed on a silicon-on insulator chip is described in WO95/08787 and a particular embodiment thereof is shown in Figure 6. The p-i-n diode phase modulator comprises a rib waveguide 18 formed in the silicon layer 19 of a silicon-on-insulator chip. Figure 6 shows the insulating layer 20 of silicon dioxide which separates the silicon layer 19 from a silicon substrate 21. A p-doped region 22 is formed in the slab region of the silicon layer 19 on one side of the rib 18 and an n-doped region 23 is formed in the slab region on the other side of the rib 18. This embodiment of the p-i-n diode phase modulator functions in the manner described in WO95/08787, i.e. a potential applied across the p-doped and n-doped regions 22 and 23 causes charge carriers to be injected across the waveguide (as illustrated by the arrows in Figure 6). This changes the effective refractive index of the waveguide and thus changes the transmission characteristics of an optical mode (shown by dashed lines in Figure 6) in the waveguide. The device can thus be operated as a phase modulator.

One or more p-i-n diode phase modulators may be used in a variety of configurations to provide an optical switch and Figure 3 illustrates a four-port Mach-Zehnder interferometer comprising two pathways extending between two four-port evanescent couplers 7 and 8 (represented in the Figures by loops

between waveguides positioned in close proximity to each other) with a first p-i-n diode phase modulator 9 in one pathway and a second p-i-n diode phase modulator 10 in the other pathway. The functioning of such an interferometer is well known. By appropriate control of the phase modulator 9 and/or 10, the effective optical lengths of the two pathways can be controlled such that the Mach-Zehnder interferometer operates as a two-way switch connecting the fibre connector 4 either with the light source 2 or with the light receiver 3. In one state of the switch, the fibre connector 4 is connected to the light source 2 and a beam dump 17, if provided (see below) is connected to the light receiver and, in the second state of the switch, the fibre connector 4 is connected to the light receiver 3 and the beam dump 17 connected to the light source 2. It should be noted that only one of the phase modulators 9 or 10 need be used to operate the switch although both are preferably provided to allow either for more sophisticated control of the Mach-Zehnder interferometer or to provide a back-up should one of the diodes fail.

A beam dump or light absorber 17 is also shown in Figure 3 connected to the fourth port of the Mach-Zehnder interferometer to absorb any light signals received on this port. In an alternative arrangement, the beam dump may be replaced by a monitor photodiode 17 or other form of receiver for monitoring the output of the transceiver.

It should also be noted that an optical switch comprising a Mach-Zehnder interferometer as described above also enables the switch to be operated in a variety of ways. It may be controlled so as to operate as a simple two-way digital switch as described above or, if desired, the coupling ratios between two states of the switch can be varied continuously to provide analog operation. The coupling ratios between the arms of the junction can also be set at the required level or adjusted at the time of shipping, on installation, or in use, to compensate for temperature variations, changes in performance over time etc. and so allow the output power to be tuned or dynamic adjustments made to compensate for changes in the transmission paths. Thus, the device can be

operated in different ways depending on the application and its requirements. This flexibility of operation thus provides for a more adaptable device and reduces costs by allowing a similar device to be used in different applications.

Figure 2 shows a similar arrangement to Figure 1 but with the light source comprising a reflector, e.g. a mirror 11, instead of an active light source. A transceiver such as that shown in Figure 2 may be one of many arranged to communicate with a central controller via the optical fibre 5. A transceiver may for instance, be provided in each user's home and one central controller provided per street or larger group of houses. In such applications, it is desirable to avoid the need for a laser diode in each transceiver. To achieve this, various arrangements have been proposed in which, during a transmit phase, light is received from a laser source situated in the central controller, via optical fibre, and is reflected from a mirror within the transceiver. The light reflected from this mirror is then modulated in order to provide the output signal of the transceiver. Opto-mechanical components, such as Fabry-Perot modulators with movable reflective components e.g. polysilicon diaphragms, have been proposed to reflect and modulate the light in such a transceiver. Such devices are relatively complex and are expensive to manufacture.

A transceiver such as that shown in Figure 2 is provided with a light receiver 3 which operates as described above and is provided with a mirror 11 which, during a transmit phase, reflects light received from a continuous wave source in a remote central controller via the optical fibre 5. Thus, when the optical switch 6 is set to connect the mirror 11 to the optical fibre 5, the mirror 11 acts as a light source reflecting light back into the fibre. However, in this mode, the optical switch 6 can also be used to modulate the outgoing light, i.e. the light reflected from the mirror 11 and transmitted to the optical fibre 5, by switching on and off the connection between the mirror and the optical fibre. This arrangement is thus a significant simplification of the prior art yet it is able to provide the required or improved operational features.

The arrangement shown in Figure 2 thus enables the transceiver to provide an output signal without the need for an active emitting device in the transceiver. An optical switch comprising one or more p-i-n diode modulators as described above can be used to provide the switching function and is sufficiently fast to modulate a narrow band return-path signal as typically required for data transmission from a home to a central controller, e.g. in the range of 10 - 150 Mbits/sec.

This type of application thus allows a high band width transmission downstream to a user with a moderate band width upstream to the central controller (which is sufficient for many applications). Another example of such an application is an in-flight entertainment system where each seat within an aircraft is provided with a transceiver for receiving multiple data and entertainment channels from a central controller within the aircraft and for communicating the user's inputs to the central controller.

The embodiment shown in Figure 2 thus has the benefit of lower manufacturing costs due to the absence of an active light emitter therein and lower maintenance costs as reliability problems which can arise with laser diodes are avoided. Problems associated with changes in the emitter's performance over time, and changes in performance with temperature are also avoided. And, as in the first embodiment, the optical switch 6 enables the transmission properties of the transmit path and receive path to be optimised during the respective time slots.

A light receiver 3 such as a photodiode also acts as a beam dump for absorbing any light received on that port of the Mach-Zehnder interferometer thus giving a good return path extinction ratio.

An optical switch employing one or more p-i-n diode phase modulators as described above can be constructed so as to switch sufficiently quickly such

that the dead time between transmit and receive time slots can be reduced to 50 nanoseconds or less, and preferably 10 nanoseconds or less.

Figure 4 shows an alternative arrangement to that shown in Figure 3. In this embodiment, an optical fibre (not shown) is connected via a fibre connector 4 to a waveguide 12 which leads to a Y-junction 13, the two arms of which form the two pathways described in relation to Figure 3. The light source 2 may be an active light source such as a laser diode or a passive light source such as a reflector.

Figure 5 shows another manner in which a transceiver similar to that of Figure 3 may be used. In this embodiment, the Mach-Zehnder interferometer has two input – output ports each of which is connected to a respective optical fibre 14, 15. Optical fibre 14 is coupled to a ring network 16 so as to transmit signals to the network in a clockwise direction around the network and receive signals therefrom travelling in a counter-clockwise direction around the network whereas optical fibre 15 is coupled to the ring network so as to transmit signals to and receive signals from the network in the opposite directions around the network.

Figures 7 and 8 illustrate the application of a transceiver such as that described above to a passive optical network (PON), e.g. between a multiplicity of home users and a central office.

Figure 7 shows a home unit 24 which is connected to receive and transmit signals over an optical fibre 25. The unit 24 preferably comprises an integrated device with each of the components integrated or mounted on the same chip. However, each component may comprise a separate chip and be connected to the other chips by optical fibres. The optical fibre 25 may carry signals of more than one wavelength, e.g. it may carry 1550 nm analog signals for cable television (CATV) channels and 1310 nm digital signals for input and output data from the home user. These signals are separated by a wavelength

division multiplexer (WDM) 26, such as a Mach-Zehnder interferometer with the 1550 nm signal directed along a waveguide or optical fibre 27 to a further receiver, such as CATV receiver 28, and the 1310 nm signal directed along a waveguide or optical fibre 29 to a single wavelength transceiver 30 such as that described above, e.g. as shown in Figure 1 or 2.

The arrangement shown in Figure 7, shows a single wavelength transceiver 30 similar to that of Figure 2. This comprises a light source 11 in the form of a mirror and a light receiver 3, each of which may be integrated on the chip with the remainder of the transceiver or provided off-chip and connected thereto by optical fibres. The light receiver 3 may comprise a photodiode which is sensitive to 1310 nm signals but not to 1550 nm signals.

Figure 8 is a schematic diagram showing the connection between a central office 31 and a plurality (n) of home units 32 connected thereto via a passive 1 x n splitter 33.

The central office 31 may comprise a 1550 nm CATV transmitter 34 and a 1310 nm digital transceiver 35 the outputs of which are multiplexed by a multiplexer/de-multiplexer 36 onto an optical fibre 37. The transmitter 34 and transceiver 35 provide signals for all n home units 32. The signal on optical fibre 37 is thus divided into n identical signals on n optical fibres 38 by the 1 x n splitter 33. Each optical fibre 38 corresponds to the fibre 25 shown in Figure 7 and each home unit 32 is similar to that shown in Figure 7.

It will be appreciated that the system shown in Figure 8 needs to be able to distinguish between the digital (1310 nm) signals received from or intended to be directed to each of the home units 32 and the 1550 nm CATV signals. This may be done, for instance, by time division multiplexing (TDM) or by sub-carrier modulation, e.g. by frequency modulation, with a different frequency used for communication with each home unit 32.

Other transmission and receiving means operating on a different wavelength to the digital transceiver may, of course, be used in place of the television transmitter and television receiver described above.

The embodiments described above comprise various optical components. These components are known in the art so will not be described further. However, it should be noted that the transceiver can be fabricated on a silicon-on-insulator chip using components described in the following publications/applications, the disclosure of which are incorporated herein:

WO95/08787 – describes integrated rib waveguides and a p-i-n diode modulator

WO97/42534 – describes a fibre connector for connecting an optical fibre to a silicon rib waveguide.

WO98/43676 – describes mounting an optical component such as a laser diode on a silicon-on-insulator chip.

WO98/35253 – describes mounting an optical component such as a photodiode on a silicon-on-insulator chip.

WO98/57205 - describes a beam dump

The reflector 11 can be in the form of a mirror fabricated in an integrated optical circuit by etching a recess within the chip with a reflective facet on one side of the recess, preferably coated with a reflective material such as aluminium or gold. Alternatively, the reflector may comprise a reflective waveguide grating that reflects light at the operating wavelength of the transceiver.

It should also be noted that although it is preferable for the light source and light receiver to be provided on the chip as described above, either or both of the

light source and light receiver may be provided off-chip and connected thereto by optical fibres connected by fibre optic connectors to the chip.